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Fragment Analysis Process for the Joint Trauma Analysis and Prevention of Injury in Combat Program

Karen Pizzolato

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14. ABSTRACT
Fragments from the threat and surrounding environment often become embedded in Service Members during an event in-theater. Analyzing these fragments is crucial to the characterization and identification of threats. Fragment analysis is one part of the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) Program. JTAPIC is a partnership program that was established at the U.S. Army Medical Research and Material Command. JTAPIC fragments are removed during autopsy by the Armed Forces Medical Examiner Systems from Service Members who were killed in action. These fragments are analyzed by the U.S. Army Research Laboratory (ARL). The analysis procedure includes the sterilization, scanning, and documentation of the physical properties of the fragments. ARL determines the elemental composition of fragments using qualitative and quantitative analysis procedures. The analysis results are used in event recreations and modeling and simulation. The results also assist JTAPIC partners with test designs and in understanding personnel vulnerabilities to threats.

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1. Background

Based on DOD 6025.21E,[1] the Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC) Program was established at the U.S. Army Medical Research and Material Command. JTAPIC is a partnership program that links the operational, medical, and material communities with the purpose of collecting, integrating, and analyzing operational and injury data. Fragment analysis is one project that was established as a part of the JTAPIC Program.

Fragments embedded in U.S. Service Members during an event in-theater are removed during autopsies by the Armed Forces Medical Examiner Systems (AFMES). These fragments are transferred to the Warfighter Survivability Branch (WSB) of the U.S. Army Research Laboratory (ARL) where they are analyzed to determine their elemental composition and origin. The results of fragment analyses are used to characterize and identify threats to assist in determining enemy techniques, tactics, and procedures (TTPs). The results are used by JTAPIC partners to support event recreations, modeling and simulation, assist with armor and personal protective equipment test designs, and assist in understanding personnel vulnerabilities to threats. All data from the JTAPIC Fragment Analysis Project is stored in the JTAPIC Fragment and Material Database. This data includes fragment photographs, physical properties, three-dimensional (3-D) scans, and elemental analysis results. The fragment processing and analysis procedures used by ARL are described herein, and examples of the analysis results are included.

2. Procedure

JTAPIC fragments are removed by a medical examiner at the AFMES during autopsy. All fragments are considered forensic evidence and are therefore accompanied by U.S. Department of the Army Form 4173. A forensic investigator from AFMES transfers all fragments to a WSB evidence custodian for transport back to ARL. The following ARL organizations are involved in the fragment analysis process: the Safety and Health Physics Branch of the Associate Director for Laboratory Operations (ADLO) Directorate and the Multifunctional Materials Branch of ARL's Weapons and Materials Research Directorate (WMRD).

[1] U.S. Department of Defense (DOD). Directive 6025.21E; *Medical Research for Prevention, Mitigation, and Treatment of Blast Injuries*; 5 July 2006.

The first step in the analysis process is to ensure that all fragments are safe for handling by ARL personnel. Prior to direct handling, all fragments are scanned for radiation. The radiation scanning is conducting by ADLO personnel through the use of a hand-held geiger counter. Once the fragments have been determined to be free of radiation, they can be logged into the ARL Fragment Evidence Logbook, which is used to track the date and time of fragment transfers. Next, photographs are taken to record the condition of the fragments upon receipt by ARL. At this time, metallic and plastic fragments are separated into two groups for sterilization.

WMRD performs sterilization to remove any potential biological hazard. Two different sterilization procedures are used. Metallic fragments are sterilized using an autoclave method. A VSR model AS12 autoclave is used to heat the metallic fragments at 100 ºC for 100 min at 17 pounds per square inch (psi) of pressure. Fragments that appear to be plastic are soaked in a 10% formalin solution for 24 h. This method ensures that the plastic will not melt while providing the same level of sterilization as the autoclave method.

After sterilization is completed, the fragments can be safely handled by the fragment analysts. Each fragment is photographed, and its physical properties are recorded. The mass, length, width, and depth of each fragment are measured, and a light microscope is used to record a basic physical description of the fragments. A second set of photographs is taken of all fragments using an L-shaped forensic evidence ruler to preserve the image of the fragment evidence.

Three-dimensional scans are taken of selected fragments. These scans, which are performed using a NextEngine HD 3-D scanner, provide fragment analysts with the exact 3-D geometry and shape factor of the fragment of interest. Two scans are recorded for each fragment. The second scan is taken in an orthogonal position in relation to the first scan. These two scans are merged using the Geomagic computer program to create a 360° 3-D representation of the fragment.

Once all physical properties have been recorded, qualitative elemental analysis is performed using Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDS). Particular cases of interest also undergo quantitative analyzing using Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES). A Hitachi S-4700 Field Emission Scanning Electron Microscope (SEM) with EDS capabilities is used for qualitative elemental analysis. Several representative areas are identified on each fragment, and a low magnification (35×) micrograph is taken of these areas. Qualitative elemental analysis is performed using EDS. This technique employs an electron beam to penetrate the surface of the fragment. The electron beam excites the surface atoms of the fragment, producing X-rays that possess energies characteristic of the elements found in the sample. A detector is used to convert the X-ray energies into voltage signals, which are sent to a pulse-processor for detection. The results are displayed as an elemental spectrum. Based on the results of the qualitative analysis and any input from the JTAPIC partners, selected fragments will undergo quantitative analysis using ICP-AES. ICP-AES is used to determine the exact elemental percentages of the trace concentrations of metals in a fragment sample, which can be used for metal alloy identification.

After the completion of all analyses, the results are recorded in the JTAPIC Fragment and Material Database. This is a database that was created by WSB to provide fragment analysts with an easily accessible storage tool. The database contains all fragment photographs, physical properties data, 3-D scans, and elemental analysis results. It also contains chain-of-custody information and medical data received from the AFMES that relates to each case.

3. Results

The following is an example of the results from one fragment analysis. The fragment was determined to be 1.33 g, with dimensions of 13.93 × 14.42 × 3.01 mm. Use of a light microscope revealed a silver colored fragment with brown matter and multiple tan and blue fibers adhering to the surface of the fragment. The physical properties, recovery location, and description of the fragment were recorded in the JTAPIC Fragment and Material Database (figure 1).

Figure 1. An example of the physical properties and description of a fragment recorded in the JTAPIC Fragment and Material Database.

A photograph of the fragment was taken with an L-shaped forensic evidence ruler (figure 2). A 3-D scan (figure 3) preserved the fragment's shape and provided the necessary geometry needed for model and simulation. Scanning was also used to determine the fragment's density, which was 2.20 grams per milliliter (g/mL).

A high-resolution (35×) image of the surface of the fragment was captured using SEM-EDS (figure 4). SEM-EDS was also used to determine the elemental composition of this fragment, which was found to be predominately copper and iron (figure 5).

The results of this fragment analysis were used to make determinations about the fragment identification and origin to assist analysts in threat characterization and determining enemy TTPs.

Figure 2. A photograph taken of the fragment using an L-shaped forensic evidence ruler.

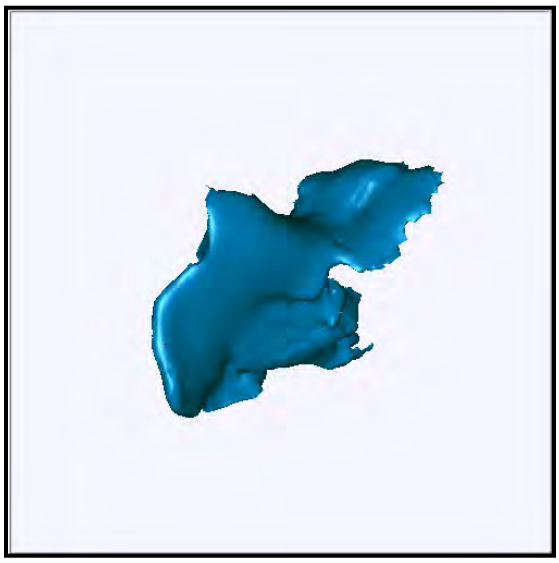

Figure 3. A 3-D model of the fragment.

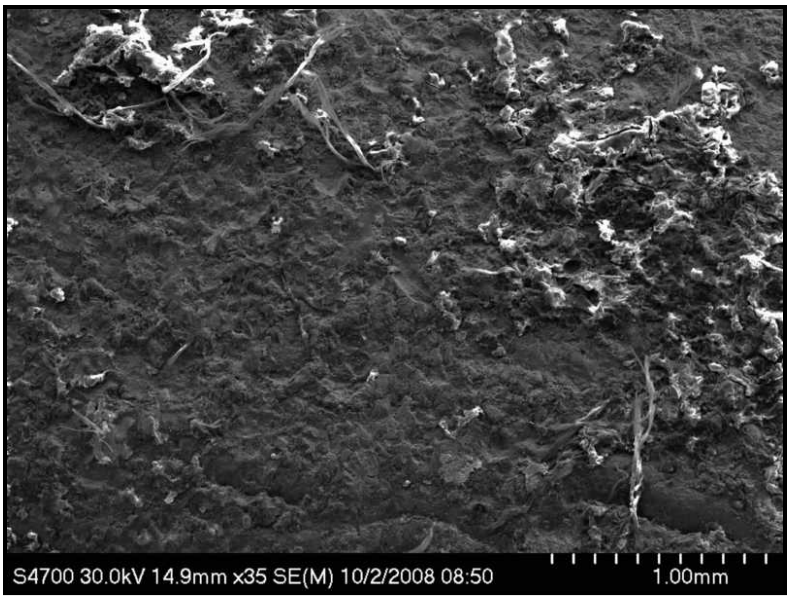

Figure 4. An SEM micrograph provides a high-resolution image of the surface of the fragment.

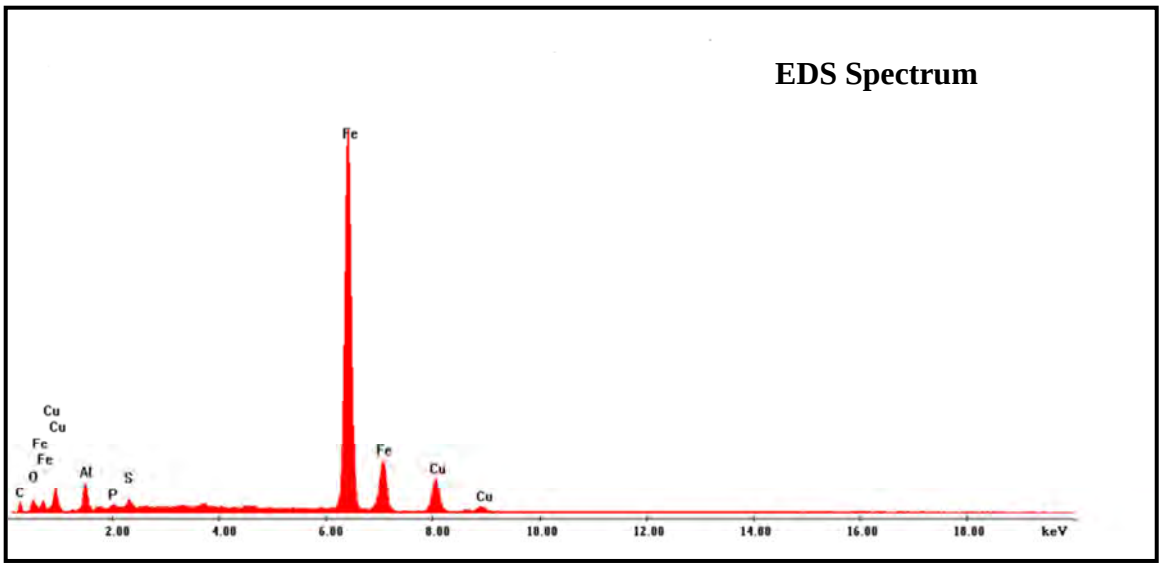

Figure 5. An EDS spectrum provides the elemental composition of the fragment.

4. Conclusions

ARL has created a procedure for processing and analyzing fragments for the JTAPIC Program. The results from ARL's fragment analyses are provided to all JTAPIC partners. The partners combine fragment results with operational and medical information to support event recreations, assist with test designs, help determine enemy TTPS, and assist in understanding personnel vulnerabilities to threats.

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